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(71) Applicant(s)
Terram Limited
(Incorporated in the United Kingdom)
Mamhilad, PONTYPOOL, Gwent, NP4 0YR,
United Kingdom

IMC Geophysics Limited
(Incorporated in the United Kingdom)
PO Box 18, Common Road,
SUTTON-IN-ASHFIELD, Nottinghamshire,
NG17 2NS, United Kingdom

(72) Inventor(s)
Anthony Jay
Peter James Jackson
David Carpenter

(74) Agent and/or Address for Service
D Young & Co
21 New Fetter Lane, LONDON, EC4A 1DA,
United Kingdom

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(54) Abstract Title
Detecting buried geotextile

(57) A geotextile structure 1 is buried between a subgrade layer 5 and a ballast layer 6 of a railway track 7 and incorporates metallic stripes 33 with well-defined edges which respond to ground-probing radar or other electromagnetic survey techniques to enable the presence of the stripes to be remotely detected from the surface. This enables the radar velocity through the ballast layer to be calculated rather than estimated and thus the depth of burial of the geotextile structure may also be accurately calculated rather than estimated from an assumed radar velocity value. Other embodiments in which the pattern of the metallic stripes encodes information e.g. relating to the geotextile (figure 8) and in which the geotextile may be laid over or wrapped around an underground feature such as a pipe or cable to facilitate remote location and/or identification of the feature (figures 9 and 10) are also disclosed.

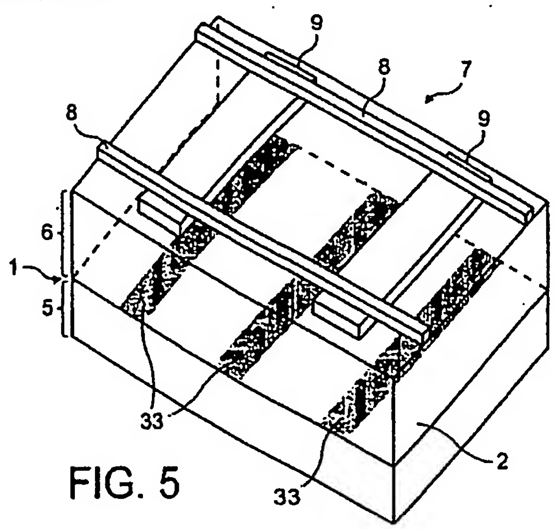

FIG. 5

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

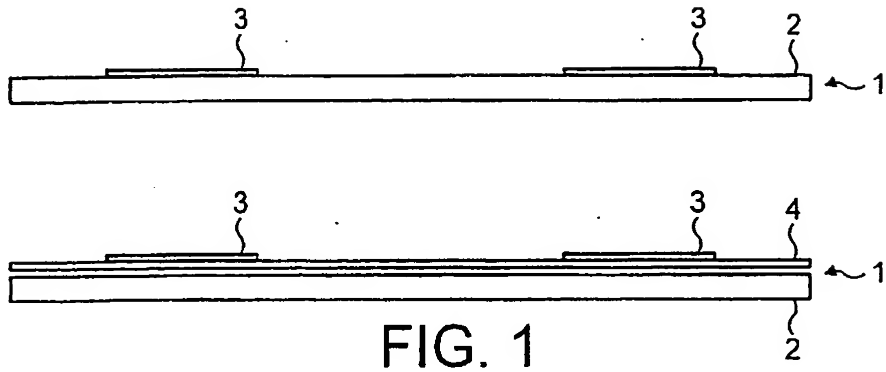

FIG. 1

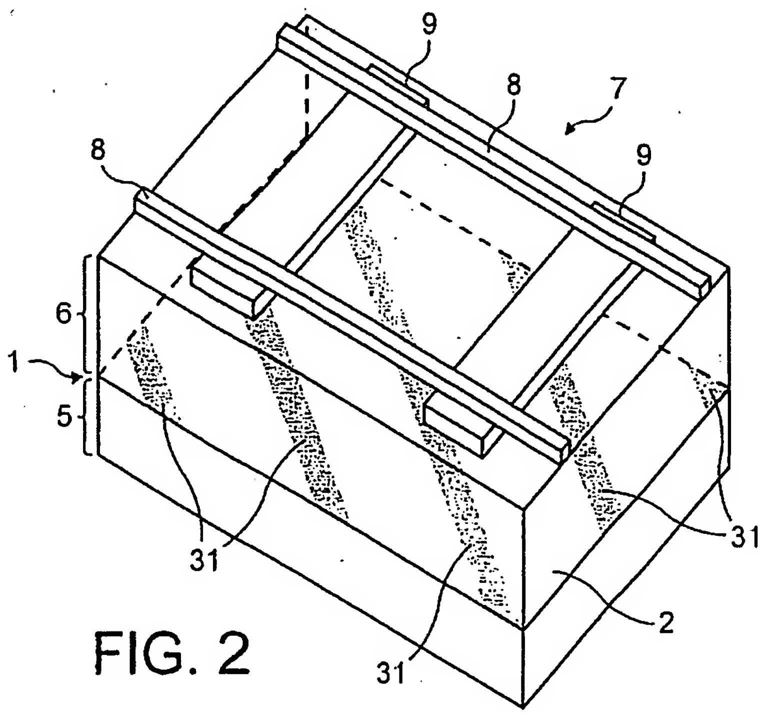

FIG. 2

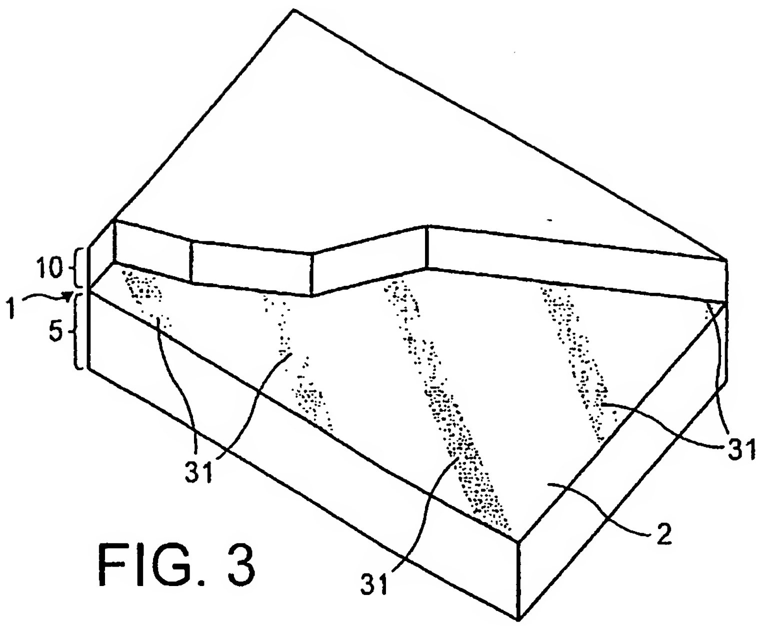

FIG. 3

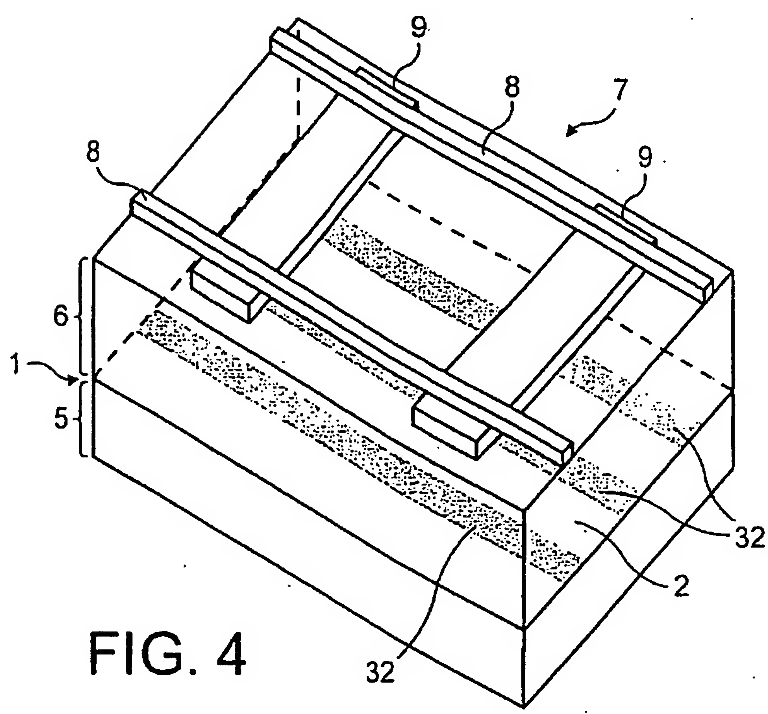

FIG. 4

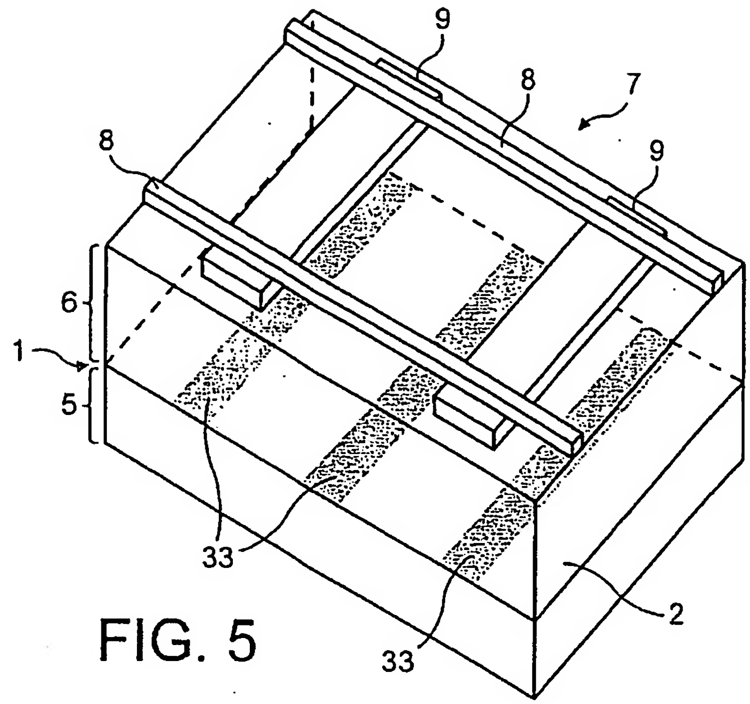

FIG. 5

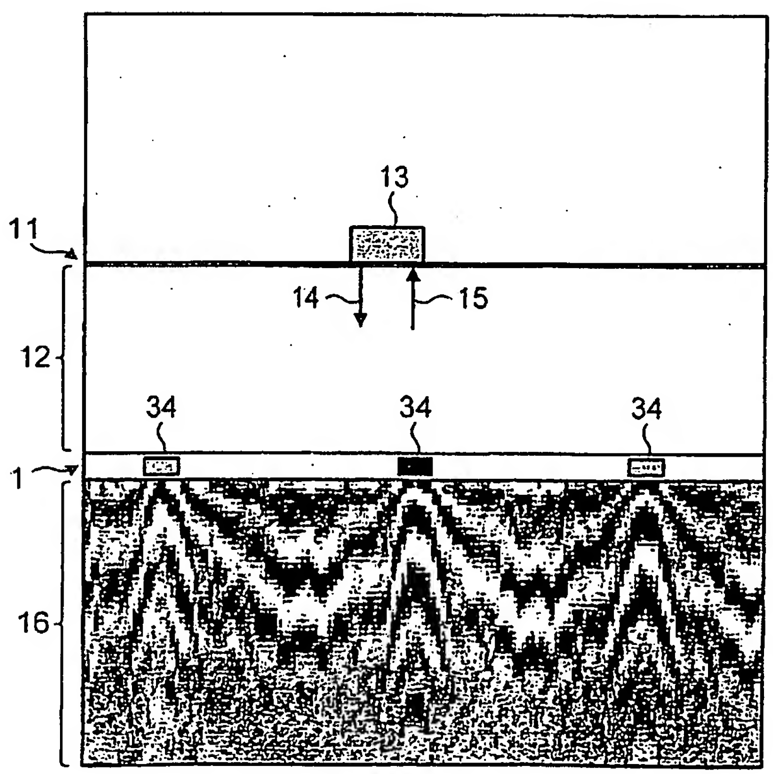

FIG. 6

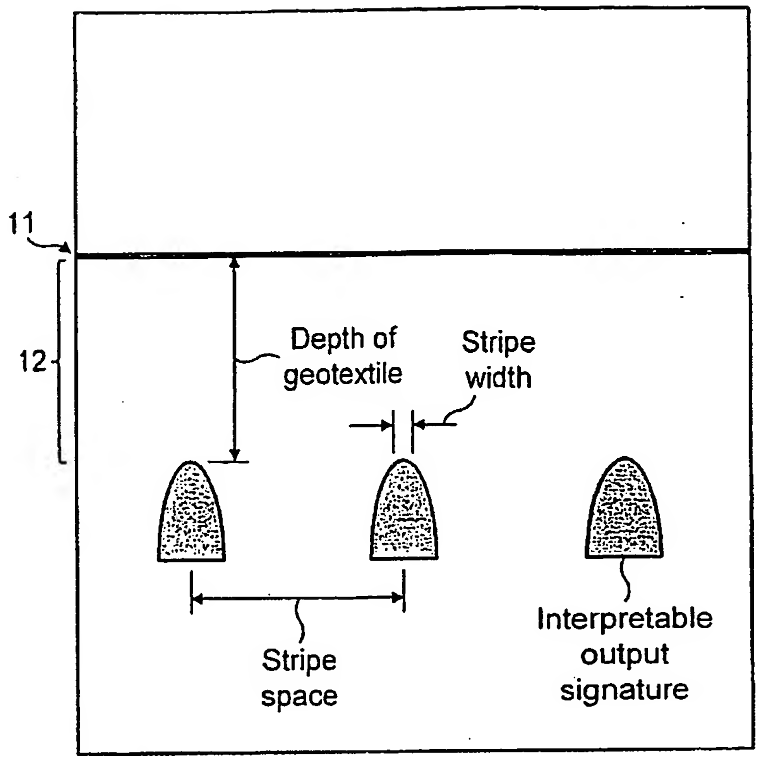
11
12
Depth of geotextile
Stripe width
Stripe space
Interpretable output signature

FIG. 7

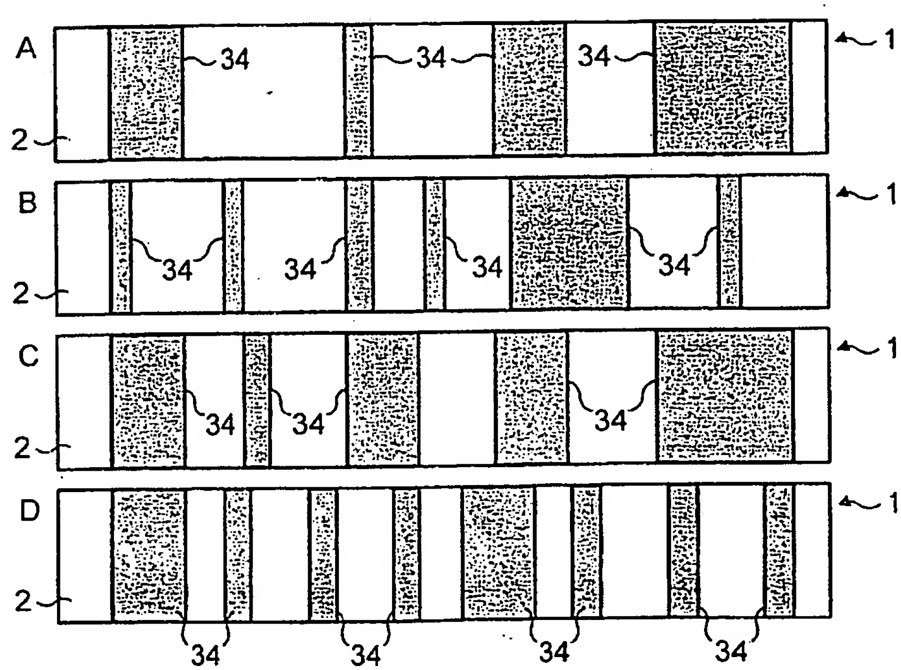
A
B
C
D
34
2
1

FIG. 8

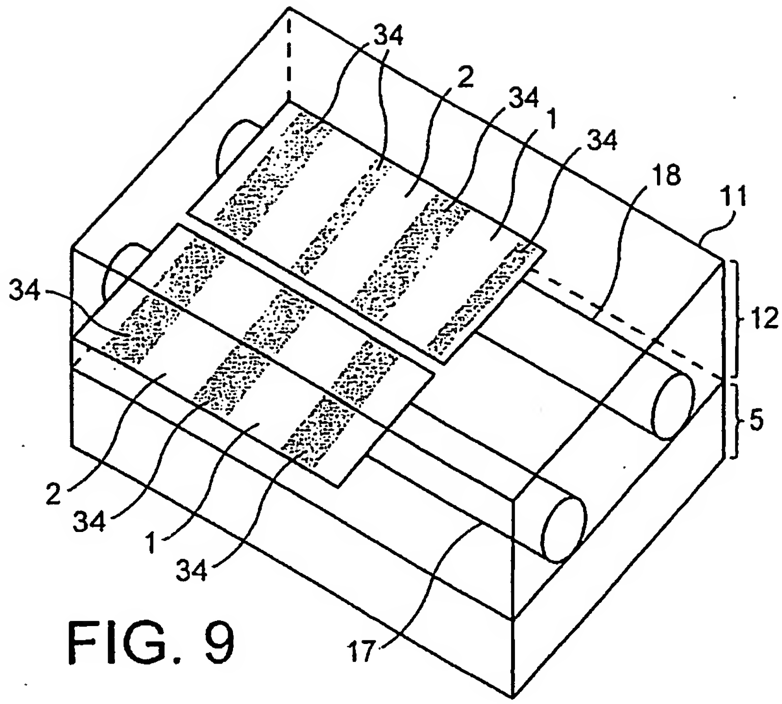

FIG. 9

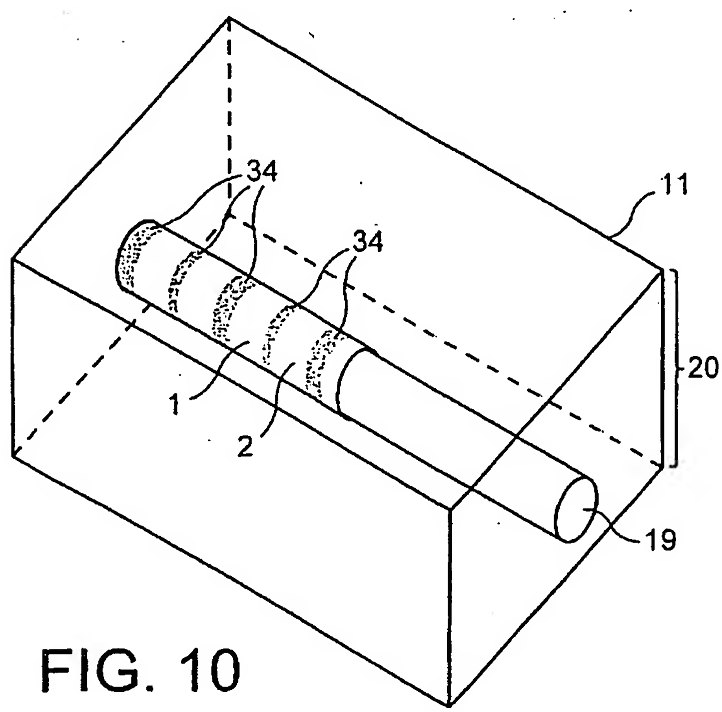

FIG. 10

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DETECTING BURIED GEOTEXTILE

FIELD OF THE INVENTION

The invention relates to detecting buried geotextile. The invention may, for example, be used in the railway industry where geotextile is laid between the ballast and underlying subgrade of a railway line. Other possible fields of use are in constructing roads, airfields and landfill sites.

DESCRIPTION OF THE PRIOR ART

It is common practice to install a sheet of geosynthetic, sometimes known and referred to as geotextile, beneath the ground in order, for example, to control the behaviour of the surrounding soil, ballast or other material, including controlling any components contained therein such as fluids, contaminants, clays etc.

A geotextile layer may be installed between the ballast and subgrade of a railway line. Alternative applications include laying a geotextile layer underneath a road or underneath an aircraft runway. Geotextile layers are also used in the construction of landfill sites.

Geotextiles are frequently installed by contractors working to a contract. A contract may specify the sort of geotextile to be used, where the geotextile is to be buried, the extent of the geotextile and the depth of the geotextile. When the civil engineering works under the contract have been completed, the customer may wish to check that the contractor has complied fully with the contract.

It is already known in some respects to interact with a buried geotextile. For example, EP-0,418,209 discloses a geotextile which has perpendicular sets of wires between which a voltage is applied to detect a fault in an adjacent insulation layer, when buried underground.

FR-2,694,773 discloses a geotextile with a metallic conductor layer through which current is passed in order to produce a heating effect.

US-4,404,516 discloses a network of electrically-conductive wires for detecting leaks, which may be incorporated in a geotextile.

US-5,980,155 discloses a geosynthetic with electrically-conductive filaments woven therein. For example, a stainless steel mesh may be incorporated in the geosynthetic.

WO-00/39405 discloses an electrically-conductive geotextile for making use of the electrokinetic phenomenon to remove water, particles, ions etc. The geotextile may incorporate metal strips, a conducting layer or bands of conductive material in order to produce the electrokinectic effect.

With the above prior art techniques, electrical connections (i.e. electrical wires) have to be provided from the surface down to the buried geotextile, specifically down to the electrically-conductive component thereof. Thus with the prior art there is no remote or indirect interaction with the buried geotextile.

Ground-probing radar and electromagnetic survey are well known and understood. Ground-probing radar has been used in the railway context in order to detect the soil and ballast interface.

In general, existing ground-probing radar technology can be used to estimate approximately the depth of a generally planar surface such as the interface between two strata (e.g. a ballast layer and an underlying subgrade layer). The radar reflects off the interface and the reflection and its timing are detected at the surface. The depth may be calculated based on the velocity of the radar pulse through the ground and the transmission duration. For different types of ground the pulse velocity will vary, and because of this variability the calculation of the depth of burial of the interface can only be an approximate estimate and will not be sufficiently accurate.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a method of remotely detecting a geosynthetic structure which is buried beneath a surface and comprises a geosynthetic layer and AC electrically-conductive material co-located with the geosynthetic layer, the method comprising:-

using a geophysical ground-probing technique to look beneath the surface and produce electromagnetic output from the AC electrically-conductive material; and

detecting and processing the electromagnetic output in order to determine that the geosynthetic structure is present.

A suitable geophysical ground-probing technique would be ground-probing radar or electromagnetic survey.

Using the method, a customer could check that a contractor has satisfactorily complied with the terms of a contract. For example, if the contract requires that geosynthetic should be installed beneath a particular area of the surface, the geophysical ground-probing technique could be used within that area to determine that the geosynthetic is buried underneath that area. For example, by moving ground-probing radar along a line starting outside the area, passing across the area, and then passing out of the area, the electromagnetic output will first of all show that there is no buried geosynthetic structure. As the path enters the relevant surface area, the output will change to show that there is now geosynthetic structure buried below the ground. As the path exits the surface area, the output will now again show that there is no buried geosynthetic structure. By passing along various different paths crossing the surface area at different angles (such as mutually orthogonal paths), a picture could be built up as to the underground extent of the buried geosynthetic. Thus it would be possible to determine whether or not the contractor has complied with the specification of the contract.

In the context of a railway line that is being laid for the first time or relaid, the contract may specify that a particular length of the railway line should have a geosynthetic layer buried therealong. The required width of the geosynthetic layer and its positioning relative to the rails of the railway line may also be specified in the contract. A ground-probing radar which has an antenna which will fit within the width of the railway track could pass along the track and detect where the buried geosynthetic layer begins and where it ends, in order to ensure compliance with the contract. The detected width of the geosynthetic layer and its positioning relative to the rails could also be detected and checked against the contract specification.

When using ground-probing radar, the function of the AC electrically-conductive material is to be a target for the electromagnetic radiation emitted by the radar (at a typical frequency range of about 10MHz to 1,000MHz) and to reflect that radiation back to the radar antenna. The preferred frequency range is about 400MHz to 1,000MHz. When using the electromagnetic survey technique, the function of the AC electrically-conductive material is to act as a target which will reradiate

electromagnetic radiation induced by a ground conductivity meter, with the frequency range typically being about 10kHz to 1MHz. The preferred frequency range is about 10kHz to 100kHz.

Because the detection is done remotely, there is no need to go to the difficulty and expense of installing and maintaining the integrity of wires running up from the buried geosynthetic structure to the surface.

In other words, the remote detection is performed entirely at or above the surface by inducing the AC electrically-conductive material to radiate information up to the surface where it may be detected and processed. There is no need for any physical link or contact between the remote detection apparatus and the target geosynthetic structure. Instead, the link up from the buried geosynthetic structure to the detection apparatus at the surface is simply an intangible electromagnetic link. Thus there is no need to excavate down to the geosynthetic structure to connect electrical wires to it.

A simplest mode of using the present invention is merely to discriminate between areas of the surface beneath which the geosynthetic structure is and is not buried.

In a more sophisticated mode, the method further comprises processing the electromagnetic output to determine the extent of the geosynthetic structure.

Thus, in the preferred embodiments, the electrically-conductive material is present substantially over the whole of the planar extent of the geosynthetic layer to ensure that the full extent of the geosynthetic structure can be detected. For example, the average distribution of the AC electrically-conductive material may be substantially uniform at the medium scale, even if at the small scale there are blank patches with no electrically-conductive material. Such an arrangement will ensure that, when viewed remotely at the large scale, the electrically-conductive material appears to be present over substantially the full extent of the geosynthetic product

Preferably, the method further comprises processing the electromagnetic output to determine the depth of burial of the geosynthetic structure. Where the AC electrically-conductive material covers the full extent of the geosynthetic layer, e.g. as a substantially coterminous layer of electrically-conductive material, the depth of burial can be estimated from the returned electromagnetic signal. Preferably, however,

for greater accuracy in determining the depth, the electrically-conductive material is present as a pattern having well-defined edges. For example, the electrically-conductive material could be painted, printed or laminated as a series of stripes on the geosynthetic layer with each stripe having two well-defined longitudinal edges.

Accurately determining the depth of burial of the geotextile is useful if the installation contract specifies the depth and the client wishes to check that the contractor has complied with the contract conditions. In the railway context, the depth of the geotextile will be the same as the depth of the layer of overlying ballast, and the contract may specify the ballast depth needed to meet the loading and speed requirements of a particular length of track..

The electromagnetic output detected by the ground-probing radar or the ground conductivity meter will vary depending on the depth of burial of the geosynthetic structure. The nature of this variation with depth is well understood. The characteristics of the detected electromagnetic output may therefore be used to calculate the depth of burial of the geosynthetic structure.

For example, we have shown that stripes of electrically-conductive paint on an electrically-insulating geosynthetic layer placed beneath approximately 50cm of railway ballast may be readily detected by using standard ground-probing radar techniques. The depth of burial may be determined by using well-established analysis techniques which make use of the rate of change of the time of arrival of the radar reflection as the horizontal position of the radar antenna is changed.

The well-defined or sharp edges of the electrically-conductive material and the fact that radar information is obtained at a number of different positions on the surface enable an accurate calculation of the burial depth to be made, unaffected by variability of the velocity of the radar pulse through the overlying ground material.

To make the geosynthetic layer detectable, it is only necessary to add the electro-conductive material to the layer to act as a detectable geophysical marker. No other components need be added to make the remote detection possible.

It is by using the AC electrically-conductive material in combination with the geosynthetic layer that it is possible to look or map beneath the surface to determine or sense the extent of the geosynthetic layer that has been laid.

The geosynthetic structure is buried underground. It will usually separate two strata, such as, in the railway context, an upper stratum of ballast and a lower stratum of subgrade.

The preferred embodiments of the geosynthetic structure are flexible in addition to being planar so as to facilitate installation between the two strata when being buried.

It is the electromagnetic interaction of the detection technique with the AC electrically-conductive material that enables an indication to be produced at the surface of the presence of the geosynthetic structure, and preferably also its extent and its depth of burial. The necessary analysis of the electromagnetic output that is detected may be achieved using a computer.

In our preferred embodiments, using the geophysical ground-probing technique comprises moving geophysical ground-probing apparatus along a path on the surface, and detecting the electromagnetic output comprises detecting the electromagnetic output at a plurality of positions along the path.

For example, moving along the path comprises moving along a strip of the surface with an antenna extending over e.g. transversely of the strip.

In our preferred embodiments, processing the electromagnetic output comprises comparing the electromagnetic output against a plurality of different electromagnetic output signatures corresponding to types of geosynthetic structures having respective arrangements of AC electrically-conductive material, and identifying the type of geosynthetic structure that is buried below the surface.

This information may, for example, be used to verify that the contractor has installed the correct geosynthetic structure required under the contract.

For example, the electromagnetic output signatures could be coded to indicate the thickness of the geosynthetic layer with which they are associated.

Alternatively, the coding could be a date such as the year of manufacture.

The electromagnetic output signatures could also indicate the sort of material of the geosynthetic layer. Combinations of the parameters could also be indicated by the coded output signatures.

Conveniently, the electrically-conductive material may be provided as different patterns on the respective geosynthetic layers. A predetermined non-regular or non-

uniform pattern may be used, such as one similar to the stripes of a bar code on a product purchased in a shop. The pattern could be coded with the desired information, such as year of manufacture, the material or sort of the geosynthetic layer and the thickness of the geosynthetic layer.

Apart from providing information regarding parameters of the geosynthetic structure, the patterns of electrically-conductive material will still enable the presence, extent, depth etc. of the geosynthetic structure as a whole to be determined.

The coded information will enable the regular monitoring over the years after installation. Thus the condition of the geosynthetic structure may be estimated years into the future after installation, in addition to continuing to check the extent and depth of burial of the geosynthetic structure to ensure that no undesirable changes have occurred since it was originally laid.

It is convenient to print or paint the electrically-conductive material onto the geosynthetic layer by using electrically-conductive paint (such as metallic paint) that could be applied in the desired (coded) pattern. Alternatively, the electrically-conductive material could be laminated onto the geosynthetic layer in the desired pattern.

As a web of the geosynthetic layer is produced it could have the pattern applied to it before the geosynthetic layer is rolled up for delivery to site for installation under the ground.

In some embodiments, the geosynthetic structure is buried in proximity to an underground feature and the type of geosynthetic structure identifies the kind of underground feature.

For example, the geosynthetic structure may overlie the underground feature.

Often, the underground feature is linear and the geosynthetic structure is also linear. For example the underground feature could be a plastic gas pipe, a plastic water pipe or a fibre-optic cable. In themselves, these may be difficult to detect as to where they are buried, and it might be necessary to perform a series of trial excavations. This is not necessary with the present invention because the geosynthetic structure is remotely detectable and thus identifies the presence and positioning of the adjacent buried underground feature.

By coding the output signature of the electrically-conductive material, the electromagnetic output information detected at the surface will indicate the nature of the underground feature. A regular or uniform pattern of the electrically-conductive material could be used. For example, stripes spaced apart every 1 metre along the length of the geosynthetic layer could indicate a gas pipe. Stripes spaced apart every 0.5 metre could indicate a water pipe, and so on. Alternatively or additionally, coding in the form of electrically-conductive bar codes as discussed above could be used as the electrically-conductive material in order to provide more information.

In many embodiments, the underground feature is part of a transmission system of a buried service, such as of a public utility.

The AC electrically-conductive material might have its own structural integrity as a layer, which could be manufactured separate from the geosynthetic layer, and the two layers would be laid on top of one another when being buried, without actually being permanently connected together. However, for ease of manufacture and for greater certainty, we prefer that the AC electrically-conductive material should be integral with the geosynthetic layer, such as by means of spraying, printing or laminating the electrically-conductive material as a pattern onto the geosynthetic layer.

According to a second aspect of the present invention, there is provided method of installing a geosynthetic structure which comprises a geosynthetic layer and AC electrically-conductive material co-located with the geosynthetic layer, the method comprising:-

burying the geosynthetic structure beneath a surface without providing an electrical connection from the AC electrically-conductive material to the surface.

Preferably, the geosynthetic structure is selected from a plurality of such geosynthetic structures each having a respective pattern of AC electrically-conductive material.

For example, each pattern may be non-regular in order to assist with the coding of information.

Preferably, each pattern comprises a series of stripes arranged side by side and having variable width and/or spacing. These stripes may resemble the bar code found on products in a shop.

For ease of manufacture, and for ease of transportation to the site, and then installation at the site, the geosynthetic structure is preferably a strip. In order to ensure the necessary extent of underground coverage provided by the geotextile, a plurality of strips (e.g. lengths cut off from a roll delivered to the site) may be buried end to end and/or side by side in order to cover the necessary extent underground. It will be usual for the edges (the longitudinal edges or end edges) to overlap. This will mean that, when sweeping the radar or electromagnetic survey over the finished installation, the buried geotextile will appear to be continuous based on the electromagnetic output received at the surface.

There is no need to electrically connect together neighbouring sheet-like portions of the overall geosynthetic structure.

The geosynthetic structure can tolerate some localized damage (e.g. punctures) to the electrically-conductive material whilst still being able to produce a satisfactory electromagnetic output when interrogated by the surface apparatus.

Preferably, there is an underground feature in situ, the plurality of geosynthetic structures have patterns coded to identify different kinds of underground features, the particular geosynthetic structure for burial is selected according to the particular kind of the underground feature in situ, and the selected geosynthetic structure is buried overlying the underground feature.

Often, the underground feature is part of a transmission system for a buried service and the geosynthetic structure is buried extending therealong.

According to a third aspect of the present invention, there is provided a geosynthetic structure remotely detectable when buried by ground-probing radar or electromagnetic survey, the geosynthetic structure comprising:-

a geosynthetic layer; and

AC electrically-conductive material co-located with the geosynthetic layer and not electrically continuous across the width or length of the geosynthetic layer.

For the preferred method of manufacturing, the geosynthetic structure is formed as a strip and the AC electrically-conductive material is integral with the geosynthetic layer.

Preferably, the electrically-conductive material defines a plurality of planar regions having marginal edge regions, and some of the edge regions extend generally

longitudinally of the geosynthetic structure and some extend generally transversely of the longitudinal direction.

By having a large number of well-defined edges, it is easier to determine the depth of burial. If it is known that the sweep direction of the radar or electromagnetic survey is only ever going to be in one direction, such as in the railway context where the sweep will be along the railway line, then the edges could simply be provided transverse to that known sweep direction. Thus, the edges of the regions of electrically-conductive material could be provided transverse to the strip of the geosynthetic structure.

The regions of electrically-conductive material may be entirely separate (such as the separate stripes of a bar-code type arrangement) or there could be some limited electrical interconnection between the regions as long as that does not diminish too much the edges of the regions that are needed to detect the depth of burial.

According to a fourth aspect of the present invention, there is provided a set of geosynthetic structures each in accordance with the third aspect of the invention, wherein the geosynthetic structures have different patterns of AC electrically-conductive material.

Often, each pattern is non-regular.

Preferably, each pattern comprises a series of stripes arranged side by side and having variable width and/or spacing.

BRIEF DESCRIPTION OF THE DRAWINGS

Some preferred embodiments of the methods and product according to the invention will now be described in greater detail with reference to the accompanying drawings in which:-

Fig. 1 is a side view showing two different versions of a geosynthetic structure in accordance with the present invention;

Fig. 2 is a perspective view showing a geosynthetic structure installed underneath a railway line;

Fig. 3 is a perspective view showing a geosynthetic structure installed underneath a road or a runway;

Fig. 4 is a perspective view showing a geosynthetic structure installed underneath a railway line;

Fig. 5 is a perspective view showing a geosynthetic structure installed underneath a railway line;

Fig. 6 is a diagram along a mock-up of a geosynthetic structure buried underneath ballast and showing real radar data underneath the buried geosynthetic structure;

Fig. 7 is an interpretation of the situation shown in Fig. 6;

Fig. 8 shows four different geosynthetic structures having different coded patterns of electrically-conductive material;

Fig. 9 is a perspective view showing geosynthetic structures installed over buried utilities; and

Fig. 10 is a perspective view showing a geosynthetic structure wrapped around a buried utility.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The figures are diagrammatic in nature and should be viewed on that basis.

Fig. 1 shows two geosynthetic structures 1. The upper geosynthetic structure 1 comprises a base layer 2 of geosynthetic material on the upper surface of which are printed or painted transverse marker stripes of electrically-conductive material 3. Thus the electrically-conductive material 3 is integral with the underlying geosynthetic layer 2.

The second, lower version of the geosynthetic structure 1 shown in Fig. 1 has an intermediate carrier layer 4 on which the stripes of electrically-conductive material 3 are painted. The carrier layer 4 is substantially the same size and shape as the geosynthetic layer 2. Although the layers 2, 4 are separate from one another and are not integral, the carrier layer 4 is installed on top of the geosynthetic layer 2 when the geosynthetic structure 1 is buried underground. Thus the electrically-conductive material 3 is co-located with the geosynthetic material of the layer 2. The geosynthetic structure 1 is usually in the form of a strip which may conveniently be delivered to the installation site as a roll. The two layers 2, 4 could be delivered as separate rolls, or else could be spirally rolled up together as alternating layers in a single roll.

Fig. 2 shows how a geosynthetic structure 1 in accordance with the present invention may be placed between a lower subgrade layer 5 and an upper, overlying layer of ballast 6. The ballast layer 6 functions as the track bed for a railway track 7 comprising a pair of spaced-apart rails 8 and transverse sleepers 9. In this embodiment, the geosynthetic structure 1 has diagonal parallel marker stripes 31 of electrically-conductive material. Thus the stripes 31 are orientated obliquely to the direction of the railway track 7.

During track construction or refurbishment, the sub-grade layer 5 is prepared. Then, the geosynthetic structure 1 is unrolled and laid as a strip on top of the subgrade layer. The ballast layer 6 is then placed on top of the geosynthetic structure 1. Finally, the railway track 7 is installed.

When the subgrade layer 5 is fine silty clay and becomes wet, a train passing overhead on the railway track 7 may cause a "pumping" action to occur in which fine soil from the subgrade layer 5 in the form of a slurry passes upwards through microscopic holes in the geosynthetic structure 1 so as to enter the ballast.

If this continues over a period of time and more and more soil is pumped up into the ballast, a phenomenon known as "pumping" failure can occur. This is when so much soil has passed up into and has contaminated the ballast that the structural integrity of the subgrade layer 5 is damaged and subsidence eventually will occur, with the railway track loosing its correct alignment.

Ground-probing radar apparatus may be passed along the railway track 7 to detect the existence, extent and depth of the geosynthetic structure 1 (as discussed later on in this specification). Additionally, the radar interrogation of the subsurface construction can detect the top of the clay from the subgrade which has passed up through the geotextile and now exists as a layer within the ballast. Thus, it is possible to obtain early warning of track "pumping" failure. Specifically, it is possible to see from analysing the received radar signal that soil is present above the geosynthetic structure, which is known to be the boundary between the subgrade layer 5 and the ballast layer 6. The depth and position of the geosynthetic structure 1 will show up clearly because of the strong radar reflection from the electrically-conductive material of the stripes 31. Even though the radar reflection from the clay which has been pumped up above the geosynthetic structure 1 will be a relatively weak reflection, its

existence may be detected and the fact that it is above the geosynthetic structure may be observed, and be taken as a warning that pumping has occurred and that pumping failure with subsidence may occur in the near future.

In the installation arrangement shown in Fig. 3, the geosynthetic structure 1 is covered with a tarmac layer 10 of a road or a runway.

The arrangement shown in Fig. 4 differs from that of Fig. 2 in that longitudinal stripes 32 of electrically-conductive material are used rather than diagonal stripes. There are three stripes 32. The central stripe runs generally along underneath the median line of the railway track 7. The outer pair of the stripes 32 run generally along underneath the rails 8 of the railway track 7.

In the embodiment of Fig. 5, the difference relative to Fig. 2 is that transverse stripes 33 are used rather than diagonal stripes.

Fig. 6 diagrammatically shows a mock-up of a geosynthetic structure 1 buried below a surface 11. The intervening fill material 12 is 50cm of ballast. Electromagnetic detection apparatus 13 is ground-probing radar and it passes from side to side as viewed in Fig. 6. and emits downwardly-directed electromagnetic radiation 14 which interacts with the electrically-conductive material 3 of the geosynthetic structure 1.

Electromagnetic radiation 15 is returned upwards by the electrically-conductive material and is detected by the apparatus 13. Real radar data from the mock-up is shown at 16 positioned (for the sake of illustration) below the geosynthetic structure 1 to show the correspondence between the features of the detected radar output and the constructional features of the geosynthetic structure 1. It may be seen that each of the stripes 34 is readily apparent as a generally-hyperbolic feature and is thus detectable in the radar output 16.

The apparatus 13 is moved along a line across the site and detects the radar output at a plurality of different positions, in order to build up the radar depth profile 16 of the site.

Fig 7 shows the interpretation that may be applied to the radar data 16. The depth of burial of the geosynthetic structure 1 may be calculated. It is also possible to calculate the spacing between the stripes 34 and the approximate width of each stripe.

Fig. 8 shows four different versions (A-D) of geosynthetic structures 1 in accordance with the present invention. Each one bears electrically-conductive material in a respective pattern. In particular, each pattern resembles somewhat a bar code of the type that is commonly applied to food products and the like. Digits or other information may be encoded by using variable widths for the individual stripes and variable spacings between successive stripes. The electrically-conductive material is shown in black. Those portions of the underlying geosynthetic layer 2 which do not bear any electrically-conductive material are shown in white.

By using the general teaching of the technique discussed in relation to Figs. 6 and 7, it may be seen that passing detection apparatus 13 longitudinally along each strip of geosynthetic structure 1 would enable the spacing between the stripes 34 and the stripe widths to be determined, so that the coded information could be read.

The coding could convey many different types of information. For example, the stripes could be used to code the date of manufacture, the type of material used for the geosynthetic layer 2 of the geosynthetic structure, the thickness of the geosynthetic layer 2 or (as discussed later on) the kind of underground feature adjacent to which the geosynthetic structure is intended to be positioned when buried. For example, version A of Fig. 8 could be encoded to indicate the presence of an adjacent water pipe. Version B could be encoded to indicate the presence of an adjacent gas pipe. Version C could be coded to indicate the adjacent presence of a fibre optic cable. Version D could be encoded to indicate the presence of an adjacent electricity cable. In this way, by scanning down from the surface, it would be possible to obtain a warning that some underground feature is buried below and exactly where it is buried, so that excavations will not accidentally damage the underground feature.

As shown in Fig. 9, respective geosynthetic structures 1 bearing appropriate encoded patterns of electrically-conductive material may be laid over the respective underground features to which they correspond. Thus, when for example installing the gas pipe 17 as shown on the left-hand side of Fig. 9, the gas pipe would firstly be laid in position and then a length of geosynthetic structure 1 with the appropriate encoding of stripes 34 would be laid along on top of the gas pipe and then completely buried beneath the fill material 12.

In relation to the right-hand side of Fig. 9, a water pipe 18 would be buried, then overlain with a geosynthetic structure 1 bearing the appropriate coding on its stripes 34, prior to being covered with the fill material 12.

Passing a radar scanner over the surface would reveal the presence and nature of the buried underground utilities, namely the gas and water pipes Preferably, the geosynthetic structure 1 is run along the full length of the relevant utility so as to provide a warning of the presence of and an identification of the nature of the utility along its full length.

Fig. 10 shows how, as applied to a structure such as a fibre optic cable 19, the geosynthetic structure 1 may be wrapped as a sheath around the cable 19. Thus the coded stripes 34 which indicate the presence of a fibre optic cable have the form of rings. The stripes 34 are shown at an exaggerated scale for reasons of clarity. The geosynthetic structure 1 may be added to the fibre optic cable 19 in the factory so as to produce a composite structure. Then the composite structure is simply buried in the ground 20 as shown in Fig. 10. Preferably, the geosynthetic structure 1 is present along substantially the full length of the fibre optic cable 19 so as to warn of the buried presence of the cable 19 along its full length as well as indicating that the underground feature is actually a fibre optic cable rather than some other utility. The geosynthetic structure 1 could perhaps be stripped away at the ends of the cable 19 to facilitate connection of the cable to other items of communication equipment.

Hitherto, there has been no effective way of remotely locating buried fibre optic cables, and it has been a common and expensive occurrence for them to be accidentally severed during roadworks and the like. This problem may be overcome with the remotely-detectable fibre optic cable shown in Fig. 10.

With the above embodiments, it may be seen that the electrically-conductive material enables the remote interrogation of the geosynthetic structure from the surface, without the need to connect electrical wires or the like down from the surface to the buried geosynthetic structure. Thus installation underground is easy and there are no wires that need to be installed running up to the surface which might be difficult and expensive to install and which might be prone to being damaged over time.

The detection apparatus, such as ground-probing radar or electromagnetic survey, is able to look down underneath the surface so as to remotely detect the

presence of the geosynthetic structure, together with preferably also determining other useful characteristics such as the horizontal extent of the geosynthetic structure, the depth of burial and the nature of any adjacent underground feature with which the geosynthetic structure is closely associated. Regular surveys over time will enable any movement of the geosynthetic structure to be monitored.

CLAIMS

1. A method of remotely detecting a geosynthetic structure which is buried beneath a surface and comprises a geosynthetic layer and AC electrically-conductive material co-located with the geosynthetic layer, the method comprising:-

using a geophysical ground-probing technique to look beneath the surface and produce electromagnetic output from the AC electrically-conductive material; and

detecting and processing the electromagnetic output in order to determine that the geosynthetic structure is present.

2. A method according to Claim 1, further comprising processing the electromagnetic output to determine the extent of the geosynthetic structure.

3. A method according to Claim 1 or 2, wherein the AC electrically-conductive material is provided as a pattern having well-defined edges and the method further comprises processing the electromagnetic output to determine the depth of burial of the geosynthetic structure.

4. A method according to any preceding claim, wherein using the geophysical ground-probing technique comprises moving geophysical ground-probing apparatus along a path on the surface, and detecting the electromagnetic output comprises detecting the electromagnetic output at a plurality of positions along the path.

5. A method according to Claim 4, wherein moving along the path comprises moving an antenna along a strip of the surface.

6. A method according to any preceding claim, wherein processing the electromagnetic output comprises comparing the electromagnetic output against a plurality of different electromagnetic output signatures corresponding to types of geosynthetic structures having respective arrangements of AC electrically-conductive material, and identifying the type of geosynthetic structure that is buried below the surface.

7. A method according to Claim 6, wherein the geosynthetic structure is buried in proximity to an underground feature and the type of geosynthetic structure identifies the kind of underground feature.

8. A method according to Claim 7, wherein the geosynthetic structure overlies the underground feature.

9. A method according to Claim 7 or 8, wherein the underground feature is linear and the geosynthetic structure is also linear.

10. A method according to any one of Claims 7 to 9, wherein the underground feature is part of a transmission system for a buried service.

11. A method according to any preceding claim, wherein the geosynthetic structure extends along between a layer of ballast and a layer of underlying subgrade of a railway line.

12. A method according to any preceding claim, wherein the AC electrically-conductive material is integral with the geosynthetic layer.

13. A method of installing a geosynthetic structure which comprises a geosynthetic layer and AC electrically-conductive material co-located with the geosynthetic layer, the method comprising:-

burying the geosynthetic structure beneath a surface without providing an electrical connection from the AC electrically-conductive material to the surface.

14. A method according to Claim 13, wherein the geosynthetic structure is selected from a plurality of such geosynthetic structures each having a respective pattern of AC electrically-conductive material.

15. A method according to Claim 14, wherein each pattern is non-regular.

16. A method according to Claim 14 or 15, wherein each pattern comprises a series of stripes arranged side by side and having variable width and/or spacing.

17. A method according to any one of Claims 14 to 16, wherein there is an underground feature in situ, the plurality of geosynthetic structures have patterns coded to identify different kinds of underground features, the particular geosynthetic structure for burial is selected according to the particular kind of the underground feature in situ, and the selected geosynthetic structure is buried overlying the underground feature.

18. A method according to Claim 17, wherein the underground feature is part of a transmission system for a buried service and the geosynthetic structure is buried extending therealong.

19. A method according to any one of Claims 13 to 18, wherein the geosynthetic structure is a strip and the strip is positioned and then buried.

20. A method according to Claim 19, wherein a plurality of the strips are positioned and buried generally in series and/or in parallel.

21. A method according to Claim 20, wherein the strips have marginal edge portions which overlap.

22. A method according to any one of Claims 13 to 21, wherein the geosynthetic structure is delivered to site wound up as a roll and lengths thereof are unrolled and cut off for burial.

23. A method according to any one of Claims 13 to 22, wherein the AC electrically-conductive material is integral with the geosynthetic layer.

24. A geosynthetic structure remotely detectable when buried by ground-probing radar or electromagnetic survey, the geosynthetic structure comprising:-

a geosynthetic layer; and

AC electrically-conductive material co-located with the geosynthetic layer and preferably not electrically continuous across the width or length of the geosynthetic layer.

25. A geosynthetic structure according to Claim 24, wherein the geosynthetic structure is formed as a strip and the AC electrically-conductive material is integral with the geosynthetic layer.

26. A geosynthetic structure according to Claim 25, wherein the electrically-conductive material defines a plurality of planar regions having marginal edge regions, and some of the edge regions extend generally longitudinally of the geosynthetic structure and some extend generally transversely of the longitudinal direction.

27. A set of geosynthetic structures each according to any one of Claims 24 to 26, wherein the geosynthetic structures have different patterns of AC electrically-conductive material.

28. A set of geosynthetic structures according to Claim 27, wherein each pattern is non-regular.

29. A set of geosynthetic structures according to Claim 27 or 28, wherein each pattern comprises a series of stripes arranged side by side and having variable width and/or spacing.

30. A method of remotely detecting a buried geosynthetic structure, substantially as herein described with reference to the accompanying drawings.

31. A method of installing a geosynthetic structure, substantially as herein described with reference to the accompanying drawings.

32. A geosynthetic structure substantially as herein described with reference to, or with reference to and as illustrated in, the accompanying drawings.

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Application No:	GB 0118663.4	**Examiner:**	A J Oldershaw
Claims searched:	1 to 32	**Date of search:**	19 April 2002

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): G1N NCSA, NCSG, NCTA, NCTC, NCTG, NDUP, NDPM, NDPX; H4D DRPW

Int Cl (Ed.7): G01V

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2163826A	(KOKUSAI DENSHIN DENWA)	1,13,24 at least
X	EP0622607A1	(NAUE-FASERTECHNIK)	24 at least
X	EP0011536A2	(SEMPLANOR)	1,13,24 at least
X	WO91/04503A1	(3M)	"
X	CA2204174	(TEXEL)	"
X	FR2728677	(BIDIM GEOSYNTHETICS)	24 at least

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